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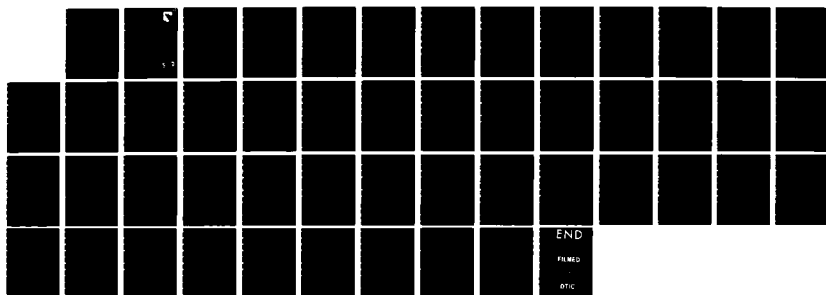
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AEROSPACE MEDICAL RESEARCH LAB WRIGHT-PATTERSON AFB OH
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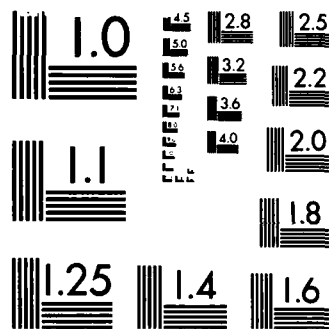
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B-52 CREW NOISE EXPOSURE STUDY

*WILLIAM H. DECKER
CHARLES W. NIXON*

AUGUST 1985

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HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

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AAMRL-TR-85-056

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER



WILLIAM L EPPERSON, LT COL, USAF
Associate Director
Biodynamics & Bioengineering Division
Armstrong Aerospace Medical Research Laboratory

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) The B-52G aircraft produces acoustic environments that are potentially hazardous, interfere with voice communications and may degrade task performance. Numerous reports from aircrews of high noise levels at crew locations have been documented for those B-52G aircraft that have been modified with the Offensive Avionics System. To alleviate and minimize the excessive noise exposures of aircrews, a study of the noise problem in the B-52G was deemed necessary. First, in-flight noise measurements were obtained at key personnel locations on a B-52G during a typical training mission. Then, extensive laboratory analyses were conducted on these in-flight noise data. The resulting noise exposure data were evaluated in terms of the various segments of and the total flight profile relative to allowable noise exposures. Finally, recommendations were developed for short term and long term approaches toward potential improvement in the B-52G noise exposure problem.					
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SUMMARY

The B-52G aircraft produces acoustic environments that are potentially hazardous, interfere with voice communications and may degrade task performance. Numerous reports from aircrews of high noise levels at crew locations have been documented for those B-52G aircraft that have been modified with the Offensive Avionics System. To alleviate and minimize the excessive noise exposures of aircrews, a study of the noise problem in the B-52G was deemed necessary. First, in-flight noise measurements were obtained at key personnel locations on a B-52G during a typical training mission. Then, extensive laboratory analyses were conducted on these in-flight noise data. The resulting noise exposure data were evaluated in terms of the various segments of and the total flight profile relative to allowable noise exposures. Finally, recommendations were developed for short term and long term approaches toward potential improvement in the B-52G noise exposure problem.

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PREFACE

This study was accomplished in the Biological Acoustics Branch, Biodynamics and Bioengineering Division, Harry G. Armstrong Aerospace Medical Research Laboratory, Aerospace Medical Division (AFSC). The effort was accomplished under Project 7231, "Biomechanics in Aerospace Operations," Task 723120, "Biodynamics and Bioengineering Support," Work Unit 72312003, "Technology Applications." Lt William H. Decker was the project officer for this effort. The authors wish to acknowledge Mr Harald Hille of the Biodynamic Environment Branch for his excellent support in data acquisition and analysis.

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INTRODUCTION

The B-52 Stratofortress is a USAF strategic heavy bomber aircraft, manufactured by The Boeing Company, Airplane Division (Wichita). The aircraft is powered by eight Pratt & Whitney J57-P-43WB turbojet engines. Two versions of the bombers are still in service, the B-52G and the B-52H. The B-52G introduced important changes in the aircraft including a redesigned wing containing integral fuel tankage, fixed underwing tanks, a new tail fin of reduced height and broader chord, and a remotely controlled tail turret that allowed the gunner to be repositioned with the rest of the crew. The final version of the aircraft, the B-52H, is powered by FF-33-P-3 turbofan engines, which provide increased unrefueled range. Additionally, the B-52H has improved defensive armament, including a Vulcan multi-barrel tailgun.

The B-52 aircraft have been progressively updated with advanced avionics under USAF improvement programs. These include electronic countermeasures (ECM), a satellite worldwide communication system, and radar warning devices. The Offensive Avionics System (OAS) is designed to upgrade the B-52's navigation and weapons delivery capabilities. This is a digital-based, solid-state system. The external sensors of the system are attached on the underneath surface of the aircraft in a pod located just forward of the Navigator and the Radar Navigator stations. The equipment racks

for the OAS sit just forward of the Instructor Navigator and are cooled by cross ventilation originating behind each rack.

PROBLEM

Flight Medicine and Bioenvironmental Engineering Services have received numerous reports of high noise levels at crew locations from crewmembers in those B-52G aircraft that have been modified with the Offensive Avionics System (OAS). A sound survey of data from the OAS configured B-52G as provided by the Bioenvironmental Engineering Services indicated that the noise exposures at the various crew locations did exceed daily allowable limits as established in AFR 161-35, Hazardous Noise Exposure (see ref). Analysis of the crewmember's noise exposure in terms of noise levels and mission duration confirmed that additional hearing protection was required. Since the hearing protection of the existing flight helmets and communication headsets are not adequate, recommendations were made that all crewmembers wear earplugs along with the standard Air Force headset or helmet. Some potential problems with audio communication were indicated for crewmembers wearing both earplugs and the headset or helmet.

(1). Some crewmembers wearing earplugs in combination with the headset or helmet reported difficulty in

discriminating the origin of audio communication transmissions; they could not tell whether the transmission came from another station on the aircraft or from a station outside the aircraft.

(2). These same crewmembers reported difficulty in recognizing the acoustic signatures of some threats.

In view of these potential problems and the intervening time of about one year since double hearing protection was implemented, a review of the noise exposure situation was deemed appropriate. The Aeronautical Systems Division (ASD/AES) requested Harry G. Armstrong Aerospace Medical Research Laboratory assistance in reviewing this noise exposure problem.

PURPOSE

The B-52G aircraft produces acoustic environments that are potentially hazardous, interfere with voice communication and may degrade task performance. Such environments could adversely affect flight crews and jeopardize mission accomplishment. The USAF Bioenvironmental Noise Data Handbook does not include the in-flight environment of the B-52G, which is required to describe the exposure noise profiles of the B-52G aircrews.

The Harry G. Armstrong Aerospace Medical Research Laboratory has prepared this technical report to provide data describing the in-flight crew noise environment and noise exposures on-board a B-52G aircraft. The methods of data collection and noise analysis are fully discussed as well as specific recommendations and guidelines for providing hearing protection that should alleviate or minimize the hazardous noise exposures being experienced by flight crews of the B-52G aircraft. This report does not address the possible problems of determining the origin of audio communication transmissions or of recognizing the acoustic signatures of some threats.

APPROACH

Information concerning the noise exposure situation on-board the B-52G was acquired from sources within ASD and the Strategic Air Command (SAC). Assessment of this information resulted in the following approach and actions.

- a. In-flight noise measurements were obtained at key personnel locations on a B-52G during a typical training mission.
- b. Extensive laboratory analyses were conducted of the recorded in-flight noise data.

c. The noise exposure data were evaluated in terms of the various segments of and the total flight profile relative to allowable noise exposures as specified in AFR 161-35, Hazardous Noise Exposure (see ref 1).

d. Recommendations were developed for short term and long term approaches to alleviating the noise exposure problems.

DATA ACQUISITION AND ANALYSES

Arrangements were made through HQ SAC/DOTT for an AAMRL engineer to obtain in-flight noise data on a B-52G aircraft. The engineer participated in a typical long duration training mission during which the noise exposures at the various crew stations were recorded and documented. All measurements were taken on-board the B-52G aircraft modified with the Offensive Avionics System (OAS) during typical speed, altitude and flight maneuver conditions. The recorded data are representative of the B-52G with the OAS modification; however, it does not necessarily represent B-52 aircraft with different equipment or structural configurations.

1. Instrumentation

Instrumentation used in these measurements was developed by AAMRL/BBE experts for in-flight noise data acquisition and has been used in the preparation of the Noise Data Handbook (ref 2). The equipment and methodology follow widely accepted state-of-the-art engineering practices. The measurement system and the data analysis system were calibrated in the laboratory and the data were corrected for the frequency response characteristics of the systems.

Microphone. A Bruel and Kjaer (B&K) 4165 one-half inch condenser microphone was used to transduce the acoustic pressure into electrical signals for in-flight recording on tape. This microphone has a free field response with a sensitivity equal to the larger 1 inch laboratory type microphone. A light, plastic foam windscreen was placed over the microphone to minimize spurious signals produced by such factors as airflow over the microphone.

Recorders. A NAGRA IV one-channel direct recorder, modified for in-flight noise measurement applications, was used to collect the acoustic data. AAMRL/BBE modifications on this small, precision recorder (battery operated) included special signal conditioning, extended low frequency response using a voltage controlled oscillator circuit, incremental logarithmic gain control and voice annotation.

2. In-flight Noise Measurements

Acoustic measurements were made at the various flight crew locations shown in Figure 1 during the different modes or conditions of the flight profile. Flight modes or conditions were defined as segments of the flight profile dedicated to a specific operation or those in which the change in the noise environment was substantial. Alphanumeric designators are used to identify crew location and flight condition with 1/A meaning measurement location 1 and flight condition A. The alphanumeric key to the measurement locations and test conditions is contained in Table 1.

Measurements were made with the microphone positioned at ear level external to the crewmember headgear in a region 0.2 to 0.3 meter from the head when a crewmember was present in that location as designated by X's in Figure 1. Measurements were also made at unoccupied stations at ear level throughout a volume where the head would normally be located. In both cases the microphone was randomly moved throughout a spherical volume approximately 0.3 meter in diameter to obtain the recorded samples. The resultant samples were analyzed in the laboratory using a 4 or 8 second integration time to obtain a power-averaged level which effectively smooths out short-duration fluctuation and appears to best describe the exposure.

Although the presence of a crewmember at a measurement location affects the resultant sound field, the magnitude of such affects is generally small and not significant in determining exposure limits. Consequently, no distinction

is made between measurements taken at occupied and unoccupied locations.

3. Noise Analyses

All recorded data were analyzed in the laboratory. A General Radio 1995 Real-Time Spectral Analyzer System is interfaced by a Hewlett-Packard 2647A Graphics Terminal to a Perkin-Elmer 3240 computer to perform these analyses. This system has been configured to provide the spectral content of the noise with third octave band amplitude resolution of 0.5 dB over a range of third octave bands centered from 25 Hz to 10,000 Hz. The system provides a selection of nine different true integration times of 1/8, 1/4, 1/2, 1, 2, 4, 8, 16 and 32 seconds.

The noise data were analyzed for six crew locations to provide the individual noise doses and Total Noise Dose (TND) in terms of percent of the daily allowable noise dose during the total training mission. The total mission profile was categorized into nine mission segments or modes for which significant changes occurred in the noise environment or a discrete operation was identified, such as take-off, climb out, normal cruise at 20,000 feet, and the like. The amount of time, in minutes, was determined for each mode of the flight profile on the basis of data collected by the on-board recording engineer and of information obtained from HQ SAC/DOTTA. The durations of each mode used

for the calculations are considered representative of typical training missions. The data were analyzed and presented in this format to allow the various segments or modes of the total mission to be examined in terms of their individual contributions to the total noise exposure at the various stations.

The noise dose was calculated for each segment of the mission from the overall sound level A-weighted (OASLA) at the ear of the crewmember and the length of the exposure. These noise dose calculations were accomplished for crewmembers wearing each of the three standard items of Air Force equipment, the HGU-26/P flight helmet, the HGU-39/P flight helmet designed for use in helicopters and the H-157 communications headset as well as for the HGU-26/P and the H-157 units worn in combination with insert earplugs. The noise dose for a segment of the flight was obtained by dividing the actual exposure time by the allowable exposure time for the value of the OASLA at the ear under the ear-cups. The result was the percentage of the daily allowable dose actually experienced by the crewmember for that condition. The noise dose percentages for the nine flight profile modes were summed to provide a Total Noise Dose or total percentage of the allowable daily noise exposure for each crew station.

RESULTS AND ASSESSMENT

Data derived from the analyses of the in-flight recordings of the noise are summarized in the appendix in terms of sound pressure levels, human noise exposure, and effectiveness of hearing protective devices in reducing the overall sound level A-weighted. Third octave band sound pressure levels of the noises are presented in graphic form in Figures 2 through 5 for three crew locations. Tables 2 and 3 contain data on the Total Noise Dose for the pilot/co-pilot and five other crew locations in percent of allowable noise dose according to AFR 161-35 Hazardous Noise Exposure. Table 2 data are for personnel wearing single hearing protection and Table 3 data are for double protection with insert earplugs worn under the earcups of helmets and headsets.

Both the Environmental Control Systems (ECS) and the OAS function at all times during the mission. In order to demonstrate the contribution of the ECS system noise to the overall noise, measurements were taken in the normal cruise 20,000 feet - 280 KIAS condition both with the ECS on and the ECS off. These data are presented for the pilot, radar navigator and gunner positions in Figures 2, 3 and 4. Although the magnitude of the contribution of the ECS noise to the overall noise varies for different stations, it is clear that the contribution of the ECS noise is significant and that it is the controlling element of the total noise environment.

Although all of the noise data are contained in tabular form in Table 4, the noise measured at the pilot/copilot, EWO/gunner, and navigator/radar navigator positions are presented for comparison in graphic form in figure 5. The spectral content of the noise differs among the various stations, however the impact of the noise exposure is not always clear from analyses of spectral data alone. The noise exposure must be determined in terms of the duration and level of the noise as well as the spectrum at the frequency regions most important to such functions as speech intelligibility and hearing.

The noise excluding characteristics differ widely for the three items of personal communications equipment included in the analyses. As a consequence, the noise doses are also different with the smallest doses occurring with the most effective protection.

1. Observations

The noise dose information derived from these analyses is summarized in Table 2 for nine segments of the flight profile, six crew stations and three different helmet/headset conditions. The total noise exposure experienced at each crew station as measured during an eleven hour training mission is presented in a bar graph in Figure 6. A number of observations are possible with these data.

a. Overall, the analyses indicate that the noise exposures for personnel at all stations, other than the flight deck, clearly exceed the allowable daily dose with crewmembers wearing either the HGU-26/P helmet or the H-157 communications headset.

b. The major contribution to the total noise dose at each crew location came from two or three segments of the training mission. The worst case situation for the EWO/Gunner stations is the low level cruise (390 KIAS) and for all other stations it is the normal cruise condition at 265 KIAS. The high noise dose for the high speed, low level cruise appears to be caused by the high noise levels whereas the high dose for the normal cruise segment appears to be the result of the long time spent in that flight mode; about 60% of the total mission.

c. Overall, the gunner station experiences the worst noise exposure followed in decreasing rank order by the EWO, navigator, radar navigator and instructor navigator positions. The gunner station experiences about 350% of the allowable daily noise dose (HGU-26/P) during the training mission.

d. The pilot and copilot stations on the flight deck experience exposures that are below the total allowable daily noise dose for crewmembers wearing either the HGU-26/P helmet or the H-157 communications headset.

e. All crew stations are below the daily allowable noise dose with crewmembers wearing either the HGU-26/P

helmet or the H-157 headset in combination with the specified insert earplugs.

f. The ECS is a significant source of the noise environment.

g. Two additional problems to that of potential hearing loss may be created by excessive noise exposure at the ear caused by inadequate hearing protection. They are:

(1) One possible effect of inadequate sound protection in environments requiring voice communications is the masking of the speech signal by the noise. In order to overcome this masking effect, crewmembers typically increase the gain of the voice communication signal until it can be heard above the noise. However, the gain of the voice communications may be increased to present the speech at such a high level that the speech signal itself may constitute a noise overdose. This analysis indicates that the double hearing protection is adequate and the insert earplug between the receiver and the eardrum keeps the speech signal from being too loud at the ear. However, crewmembers who use single protection may experience increased hearing risk from the high level of the speech signal, because of the requirement to keep the speech signal-to-noise ratio high enough for adequate voice communication.

(2). The perception of non-voice audio signals may be degraded and distorted for some crewmembers by the masking effect of the noise, the high level of the

speech signal at the ear or by a temporary hearing loss that may be caused by the high level acoustic signals, particularly for long duration missions.

DISCUSSION AND RECOMMENDATIONS

Various approaches applicable to the minimization of the noise problem for the B-52G crewmembers are possible. Some approaches can be utilized immediately with little effort, others are in various stages of development and still others involve potential directions that might be coordinated and implemented with AAMRL/BB.

The most positive short term solution to the sound exposure crew protection problem is for the crewmembers to continue to wear the combination hearing protection with insert earplugs under the flight helmets and headsets. Either the EAR or the V-51R earplug may be used under the helmets and headsets. It is important that crewmembers obtain a good acoustic "fit" with the insert protectors and retain that fit while wearing earplugs during the mission.

Another approach is the application of noise control principles to the configuration and location of the vents and diffusers of the ECS system. It appears that a primary source of the overall noise exposure in this aircraft is the ECS system and that the performance characteristics of the system in terms of noise may not comply with MIL 8806 as required by MIL-E-87145 (USAF) on Airborne Environmental Control Systems (1980). Analyses could be made of the

present system noise relative to the design specification and of the cost effectiveness of a redesign of the outlets and diffusers to appropriately reduce the noise.

During the entire mission, about 60% to 80% of the total allowable noise dose is experienced by personnel who wear the double hearing protection. Consequently, it might be acceptable to temporarily remove the insert earplug for short periods of time during other than the worst noise conditions. It is fully recognized that the use of insert earplugs in combination with the helmet and headset is less convenient than using either single device. However, when properly used and even with occasional removal and reinsertion of the earplug, personnel properly fit with the devices should be fully protected from adverse effects of the noise on hearing.

It is also recommended that B-52G aircrew members be provided audiometric monitoring at frequent intervals to identify possible changes in their hearing that might be related to inadequate operation of or improper use of the combination hearing protection during missions. Administration of audiograms as frequently as monthly should constitute a reasonable monitoring program for the B-52G aircrews. The time periods between repeat audiograms could be lengthened for monthly audiograms that show no changes in hearing.

The HGU-39/P flight helmet designed for use in helicopters should provide good single unit sound protection in all

the B-52G noise environments except at the gunner station. However, this helmet was designed for use with a chin strap and does not accept an oxygen mask bayonet system. Consequently, the helmet has not been evaluated specifically for use in the B-52G or other flight environments requiring an oxygen mask. Modification of the HGU-39/P to accept the bayonet connectors of the oxygen mask might allow it to be subjectively evaluated by crewmembers for noise attenuation relative to the HGU-26/P during various segments of the mission provided other features of the helmet do not prevent it from satisfying SAC flight safety requirements. Use of the HGU-39/P during segments of the mission could reduce overall noise exposure of the crewmembers.

At present, the HGU-55/P helmet is replacing the HGU-26/P helmet in operational situations throughout the Air Force. The HGU-55/P could possibly provide greater hearing protection than the HGU-26/P; but at this date, the laboratory has not accomplished hearing protection and voice communications performance evaluations. These helmets are scheduled to be investigated by AAMRL in the near future and the performance characteristics quantified.

The Armstrong Aerospace Medical Research Laboratory is conducting a program jointly with the Aeronautical Systems Division's Life Support SPO to develop an active noise reduction (ANR) system for application to the Air Force standard flight helmet and communications headset. The active noise reduction operates by sampling the noise under

the earcup, changing its phase and presenting it out-ofphase under the earcup so that it cancels or eliminates some of the noise present. The ANR system should provide additional sound protection, especially in the low frequency range, to that provided by the passive headset and earcup systems. This ANR system will be developed in several phases. The first phase has produced a prototype ANR system that demonstrates about 20 dB of active noise reduction in addition to the passive attenuation in the frequency range below 2,000 Hz. The present phase is emphasizing increased performance by expanding the frequency range at which active noise reduction occurs. It will also provide demonstration models of the ANR system incorporated in flight helmets and headsets for test and demonstration in operational environments. The follow-on phase will concentrate on miniaturization, flight-worthiness and increased user comfort. The goal for the ANR system is to provide equal or better speech intelligibility, greater sound protection and increased acceptability relative to those of the present standard systems. The goal for the final operational ANR system is to provide enhanced speech intelligibility in addition to the better sound protection and acceptability.

CONCLUSION

This technical report describes the measurement and analyses of the noise exposures at crewmember locations on

the B-52G aircraft during a training mission. Noise doses were calculated for segments of the mission and for the total mission for crewmembers wearing standard in-flight headwear on the basis of allowable daily exposures specified in AFR 161-35, Hazardous Noise Exposure. The Total Noise Dose exceeded the allowable daily noise exposure at all crew locations except the flight deck. These exposures create a potential risk of noise induced hearing loss, of interference with voice communications and of degradation of the perception of audio signals. The hearing of exposed crewmembers should be monitored with periodic audiometric tests.

The use of double hearing protection, earplugs in combination with the helmet or headset, provides satisfactory protection from noise induced hearing loss and should continue to be required of crewmembers. Other potential solutions to this problem are treatment of the ECS system to reduce noise, consideration of modified HGU-39/P helmets if acceptable to flight safety and continued development of the active noise reduction system and earcup programs. These latter efforts could profit from increased interaction with SAC aircrews.

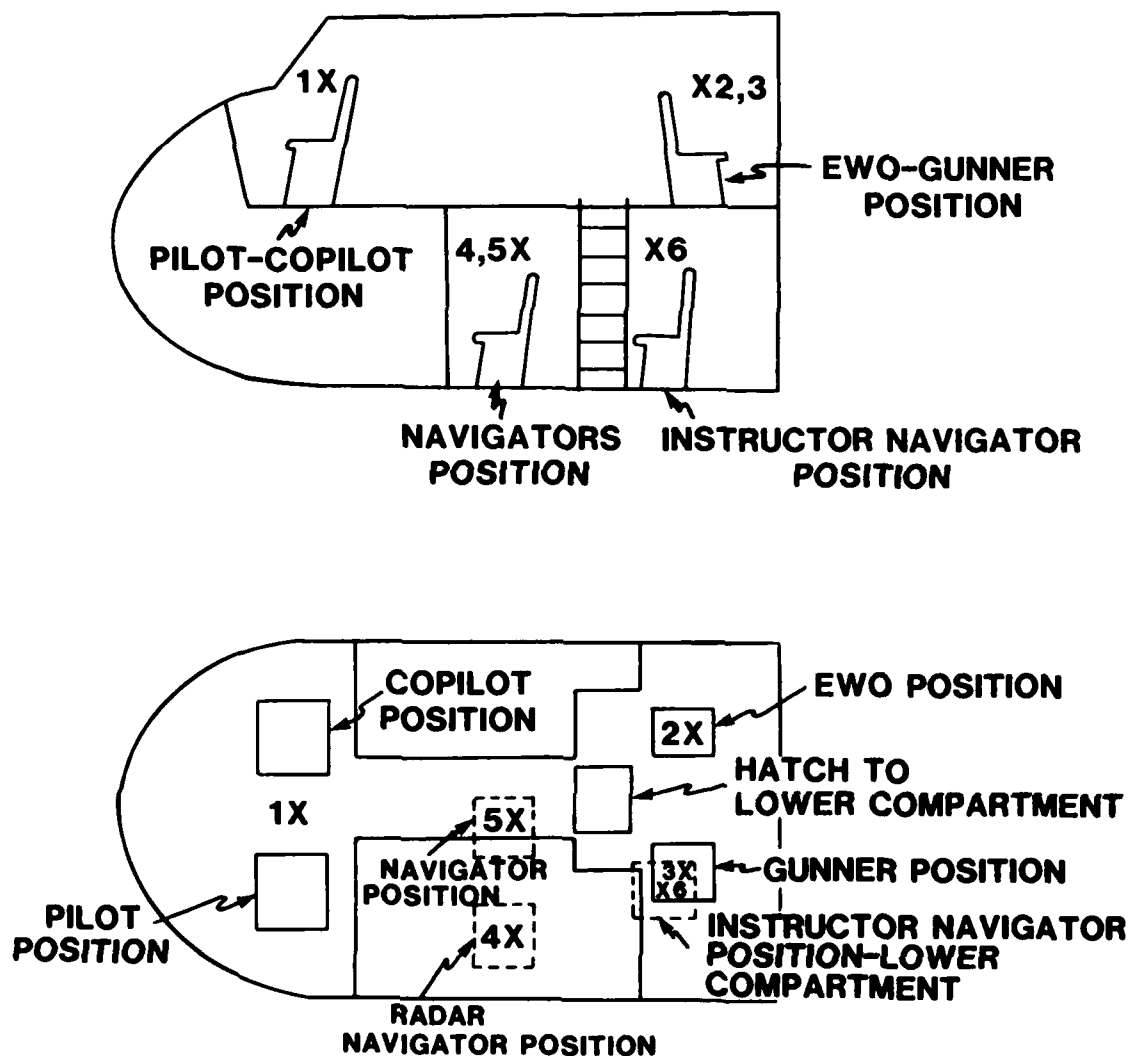
The above analyses, observations and comments are offered as guidance toward potential improvements in the B-52G noise exposure problem. There appears to be no "off-the-shelf", immediate, total solution to this problem, either in terms of personal hearing protection/communications equipment or on-board system modification. The

various avenues that remain open should be pursued as potential remedies to improve the overall situation.

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1. "Hazardous Noise Exposure", U.S. Air Force Regulation 161-35, April 1982.
2. Cole, John N. "USAF BIOENVIRONMENTAL NOISE DATA HANDBOOK: Organization, Content and Application", AMRL-TR-75-50, Vol. 1.

Fig. 1. POSITION OF MICROPHONE AT THE DIFFERENT MEASUREMENT LOCATIONS IN THE B-52G AIRCRAFT



NOTES - X MARKS THE LOCATION AT WHICH NOISE MEASUREMENTS WERE TAKEN. NUMBERS BY Xs REFER TO MEASUREMENT LOCATIONS AS LISTED IN TABLE 1.

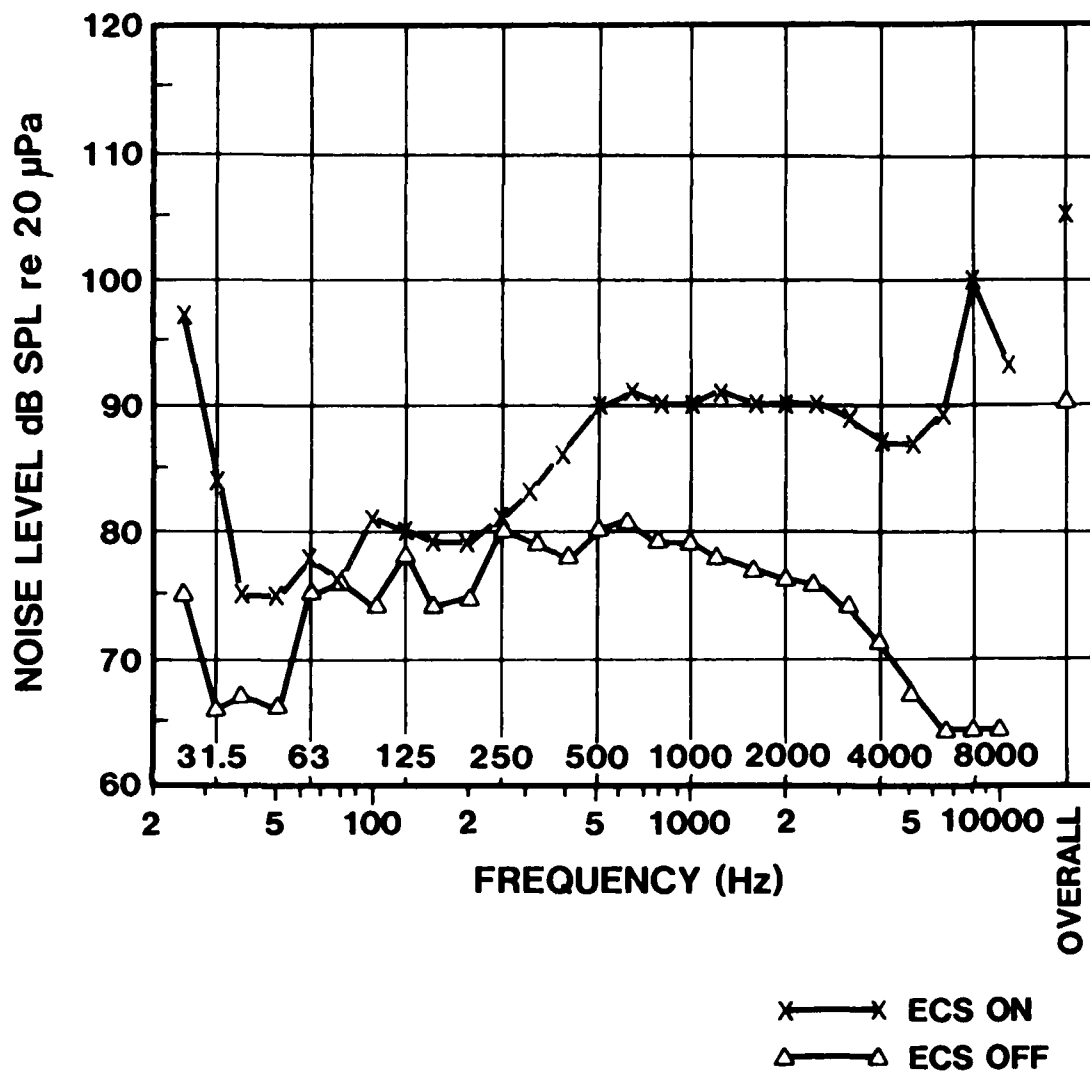


Figure 2
NOISE LEVELS MEASURED AT PILOT/COPILOT
POSITION AT NORMAL CRUISE 20,000'-280 KIAS
WITH ECS ON VS OFF

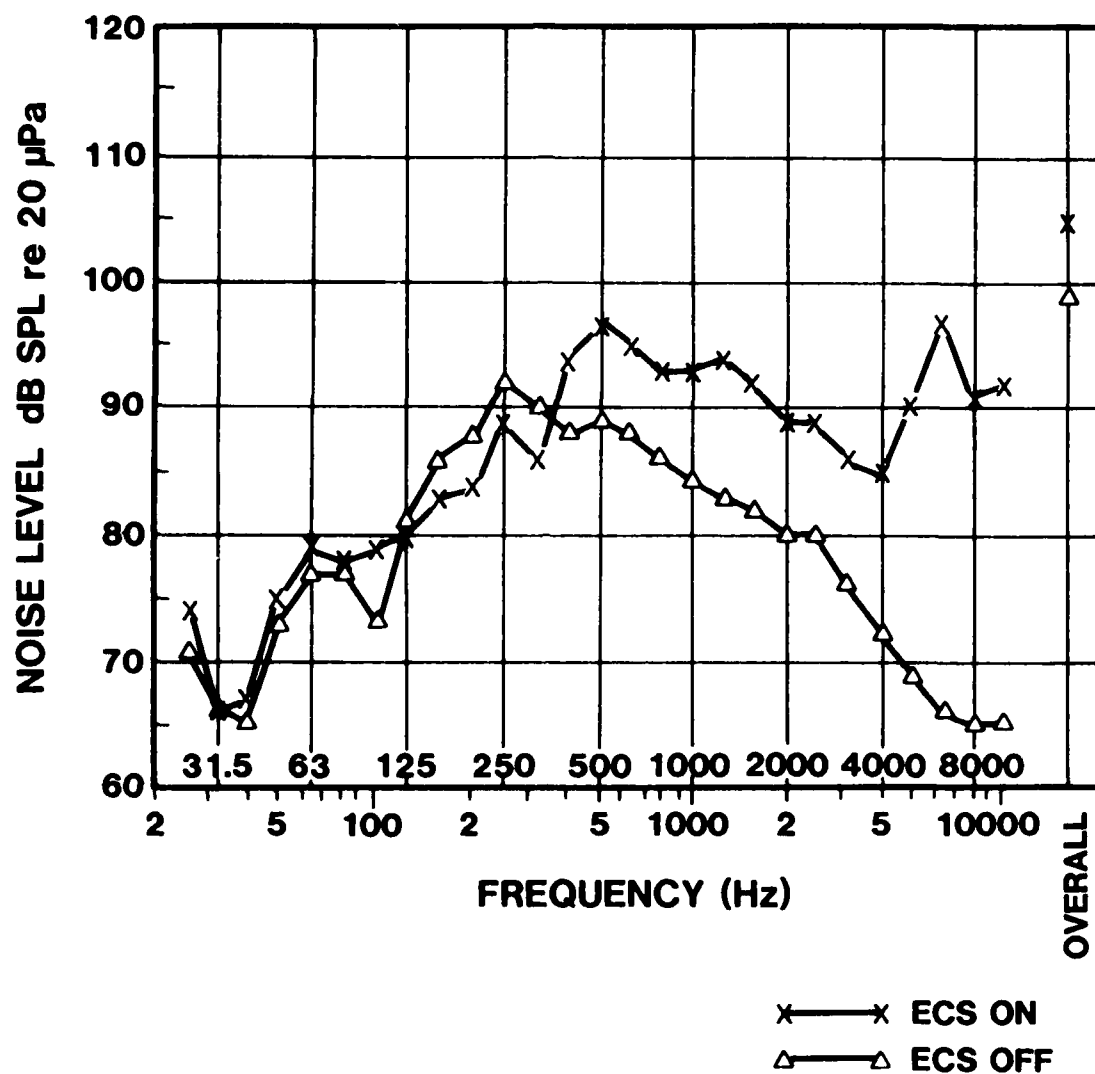


Figure 3
NOISE LEVELS MEASURED AT RADAR NAVIGATOR
POSITION AT NORMAL CRUISE 20,000'-280
KIAS WITH ECS ON VS OFF

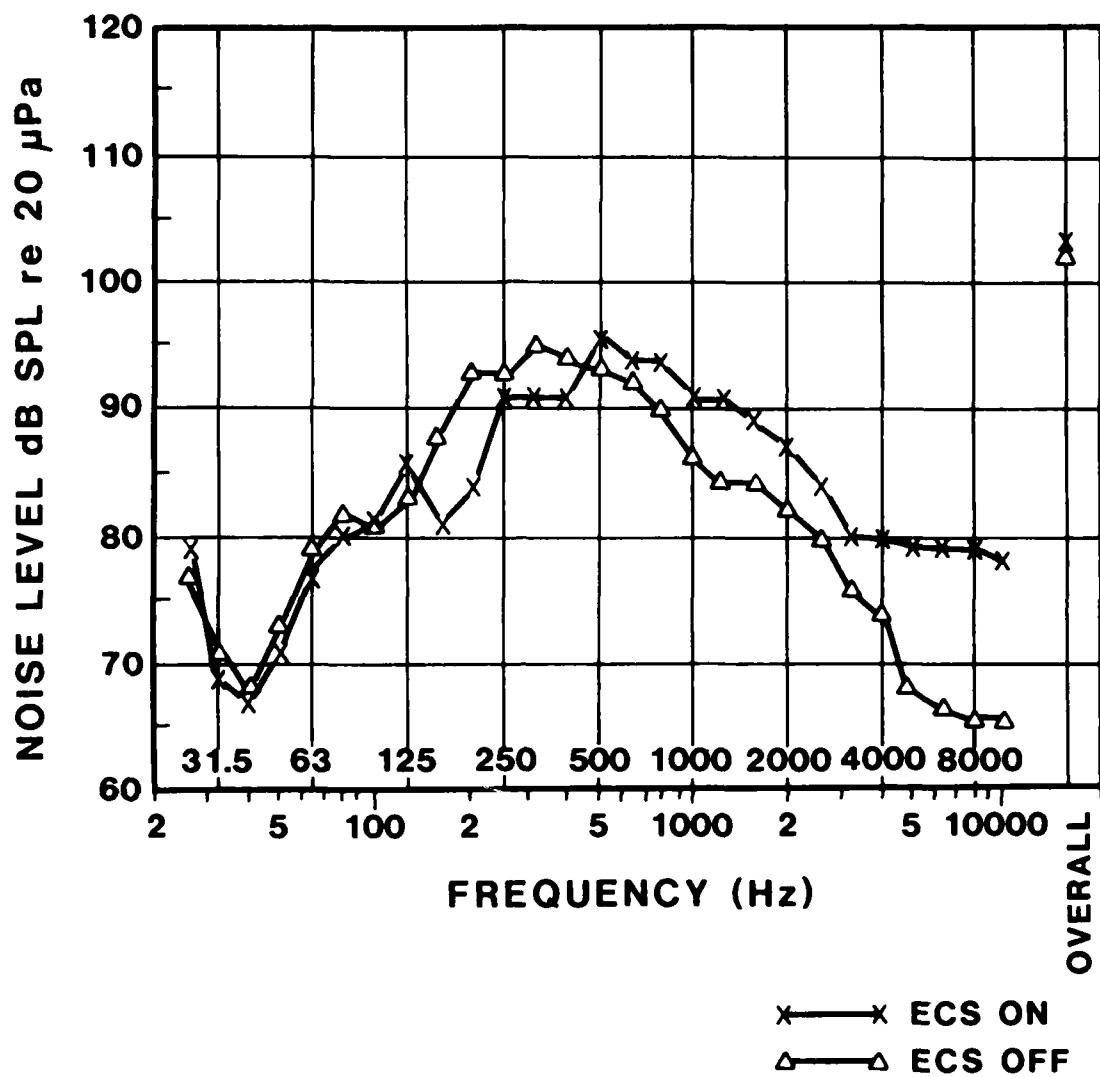


Figure 4
NOISE LEVELS MEASURED AT GUNNER
POSITION AT NORMAL CRUISE 20,000'-
280 KIAS ECS ON VS OFF

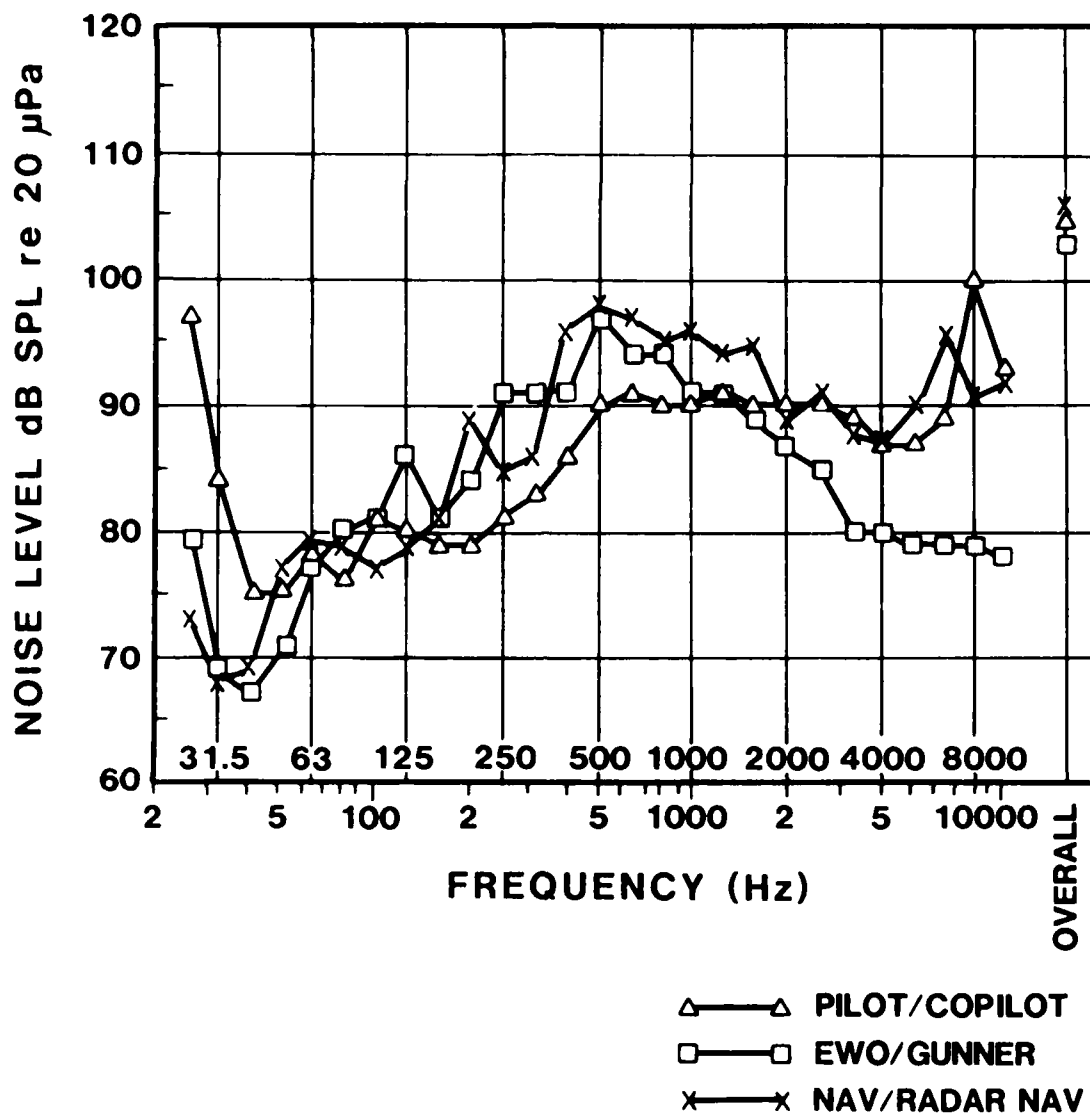





Figure 5

COMPARISON OF LEVELS OF NOISE MEASURED
AT PILOT/COPILOT, EWO/GUNNER AND
NAV/RADAR NAV POSITIONS AT NORMAL
CRUISE 20,000'-280 KIAS WITH ECS ON

B-52G

NOISE EXPOSURE

- PERSONAL EQUIPMENT
WORN BY AIRCREW

-  HGU-26/P
-  H-157
-  HGU-26/P OR
H-157 W/INSERT
EAR PLUGS

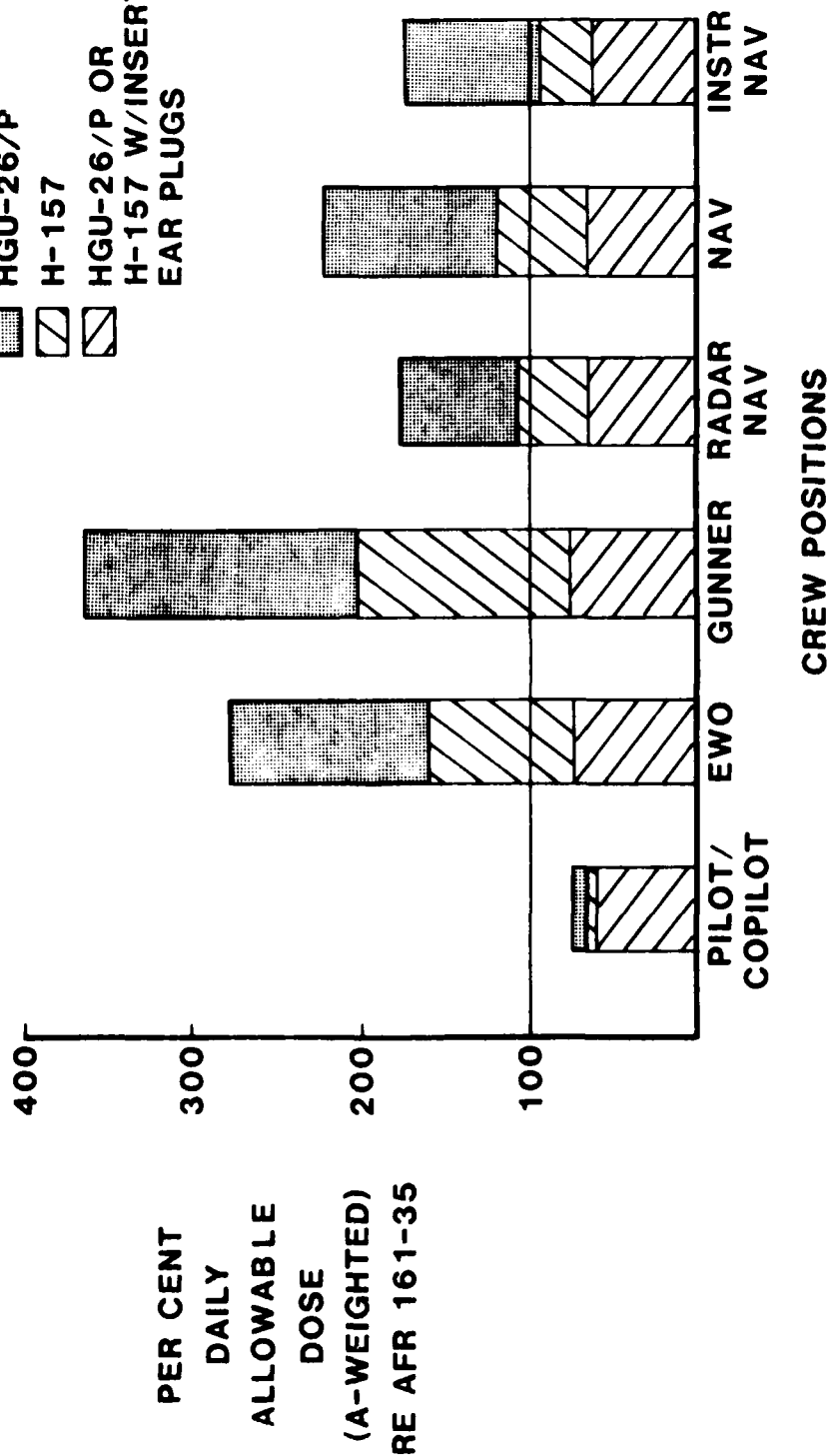


Figure 6. B-52G AIRCREW NOISE EXPOSURES MEASURED DURING AN ELEVEN HOUR TRAINING MISSION

TABLE ONE

MEASUREMENT LOCATIONS AND TEST CONDITIONS
 B-52G, WURTSMITH AFB, 8 AUG 84
 SERIAL # AF 58-0217

Location	Position	Height Above Deck
1	C/L Pilot and Copilot	Seated Head Level
2	EWO Station	Seated Head Level
3	Gunner	Seated Head Level
4	Radar Navigator	Seated Head Level
5	Navigator	Seated Head Level
6	Instructor Navigator	Seated Head Level

Condition	Description
A	Takeoff, ECS Off
B	Climb to 5000' - 280 KIAS - ECS On
C	Climb to 10,000' - 280 KIAS - ECS On
D	Normal Cruise - 20,000' - 280 KIAS - ECS On
E	Normal Cruise - 20,000' - 280 KIAS - ECS Off
F	Cruise V_{max} - 20,000' - 390 KIAS - ECS On
G	Cruise V_{max} - 20,000' 390 KIAS - ECS Off
H	Normal Cruise - 31,000' - 265 KIAS - ECS On
I	Cruise V_{max} - 31,000' - 310 KIAS, 84M - ECS On
J	Descent to 17,000' - 285 KIAS - ECS On
K	Low Level Cruise - 500' - 280 KIAS - ECS On
L	Low Level Cruise - 500' - V_{max} - 390 KIAS - ECS On

CONDITION	TIME FA CONDITION MIN.	PILOT & COPILOT			EWO STATION			GUNNER STATION			RADAR NAV STATION			NAVIGATOR STATION			INSTRUMENT NAV STA		
		HGU 26 P	H 157	HGU 39	HGU 26 P	H 157	HGU 39	HGU 26 P	H 157	HGU 39	HGU 26 P	H 157	HGU 39	HGU 26 P	H 157	HGU 39	HGU 26 P	H 157	HGU 39
TAKE OFF	2	1.67	1.18	0.42	4.00	2.35	0.99	4.00	2.35	0.99	6.67	4.76	1.98	6.67	4.76	1.98	4.76	2.35	1.17
CLIMB OUT	12	1.49	1.25	1.25	7.06	4.21	1.77	7.06	4.21	1.77	8.39	4.21	2.50	8.39	4.21	2.50	10.00	7.06	2.97
NORMAL CRUISE 20 000 280 KIAS ECS ON	15	1.56	1.56	1.56	3.12	1.56	1.56	3.12	1.56	1.56	3.12	1.86	1.56	4.43	2.21	1.56	2.63	1.86	1.56
CRUISE Vmax 20 000 390 KIAS ECS ON	25	6.19	3.68	2.60	35.21	17.48	8.77	50.00	24.75	10.42	14.71	7.38	3.10	17.48	8.77	3.68	12.38	6.19	3.10
NORMAL CRUISE 31 000 265 KIAS ECS ON	340	35.42	35.42	35.42	70.83	42.13	35.42	70.83	35.42	35.42	50.07	35.42	35.42	100.30	50.07	35.42	70.83	35.42	35.42
CRUISE Vmax 31 000 310 KIAS ECS ON	50	8.76	5.21	5.21	14.75	8.76	5.21	29.41	14.75	7.36	20.83	10.42	2.17	20.83	12.38	5.21	17.54	8.76	5.21
LOW LEVEL CRUISE 500 280 KIAS ECS ON	60	6.25	6.25	6.25	14.85	8.84	6.25	21.05	12.50	6.25	25.00	14.85	7.44	21.05	12.50	6.25	14.85	8.84	6.25
LOW LEVEL CRUISE 500 Vmax - 390 KIAS	50	10.42	7.36	5.21	119.05	70.42	34.96	166.66	100.00	49.51	41.67	24.75	12.38	34.97	20.83	8.76	35.29	17.54	10.51
DESCENT & LANDING	26	2.71	2.71	2.71	9.12	4.55	2.71	9.12	4.55	2.71	7.67	3.83	2.71	7.67	3.83	2.71	6.44	3.22	2.71
TOTAL NOISE DOSE (PERCENTAGE ALLOWABLE DOSAGE)		74.47	64.62	60.63	277.99	160.30	97.65	361.25	200.09	115.99	178.13	107.48	69.26	221.79	119.56	68.07	174.72	91.24	68.90

TABLE 2. NOISE DOSE OF CREWMEMBERS WEARING SELECTED COMMUNICATION HEADSETS UNDER VARIOUS CONDITIONS DURING TYPICAL TRAINING MISSION

★ HGU-28/P WITH E-A-R EARPLUGS				★★ H-157 HEADSET PLUS V-SIR EARPLUGS									
CONDITION	TIME EA CONDITION (MIN)	PILOT & COPILOT		FWO STATION		GUNNER STATION		RADAR NAV STATION		NAVIGATOR STATION		INSTRU NAV STA	
		HGU 28/P	H 157	HGU 28/P	H-157	HGU 28/P	H-157	HGU 28/P	H 157	HGU 28/P	H 157	HGU 28/P	H 157
TAKE - OFF	2	★★ 0.21	★★ 0.25	★★ 0.42	★★ 0.50	★★ 0.42	★★ 0.50	★★ 0.70	★★ 0.99	★★ 0.70	★★ 0.99	★★ 0.59	★★ 0.99
CLIMB OUT	12	1.25	1.25	2.10	2.10	2.10	2.10	2.97	2.97	2.97	2.97	1.25	1.25
NORMAL CRUISE 20 000' 280 KIAS-ECS ON	15	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
CRUISE V _{max} 20 000' 390 KIAS-ECS ON	25	2.60	2.60	5.21	5.21	5.21	6.19	2.60	2.60	3.10	2.60	2.60	2.60
NORMAL CRUISE 31 000' 265 KIAS-ECS ON	340	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42
CRUISE V _{max} 31 000' 310 KIAS-ECS ON	50	5.21	5.21	6.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
LOW LEVEL CRUISE-500' 280 KIAS-ECS ON	60	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
LOW LEVEL CRUISE - 500' V _{max} - 390 KIAS	50	5.21	5.21	14.75	17.54	17.54	20.83	8.76	7.36	7.36	6.20	6.20	5.21
DESCENT & LANDING	26	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71
TOTAL NOISE DOSE (PERCENTAGE ALLOWABLE DOSAGE)		60.42	60.46	73.63	76.50	76.42	80.77	66.18	65.07	65.28	63.91	61.79	61.20

TABLE 3. NOISE DOSE OF CREWMEMBERS WEARING SELECTED COMMUNICATION HEADSETS IN COMBINATION WITH EARPLUGS UNDER VARIOUS CONDITIONS DURING TYPICAL TRAINING FLIGHT

A P P E N D I X

TABLE: MEASURED SOUND PRESSURE LEVEL (DB)														IDENTIFICATION:	
1/3 OCTAVE BAND															
NOISE SOURCE/SUBJECT: (OPERATION:)														OMEGA 3.2	
B-52G														TEST CW-084-002	
INFLIGHT CREW NOISE														RUN 01	
()														AUG 07 85	
()														PAGE F1	
LOCATION/CONDITION															
FREQ (HZ)	1/A	1/B	1/C	1/D	1/E	1/F	1/G	1/H	1/I	1/K	1/L	1/J	2/D	2/E	2/F
25	96	87	84	97	75	82	82	77	80	99	90	78	79	77	82
31.5	85	77	76	84	66	77	75	70	71	83	83	70	69	67	78
40	86	79	79	75	67	78	77	72	74	78	82	73	66	67	80
50	86	78	79	75	66	76	81	72	74	77	82	68	70	71	83
63	93	82	81	78	75	82	88	76	81	84	94	72	74	77	87
80	90	79	77	76	76	83	87	76	83	81	95	71	79	81	93
100	101	80	80	81	74	85	83	76	80	80	87	72	79	80	93
125	104	83	82	80	78	84	85	77	81	82	86	72	86	84	100
160	100	82	82	79	74	81	82	75	79	82	86	69	82	85	99
200	104	84	85	79	75	82	82	77	79	82	84	72	87	89	97
250	99	86	87	81	80	87	90	78	82	85	89	75	92	96	102
315	98	88	88	83	79	91	88	78	83	87	91	77	92	93	102
400	99	88	88	86	78	89	89	81	86	88	92	77	92	92	103
500	101	91	90	90	80	95	92	85	90	89	93	81	94	94	104
630	99	90	90	91	81	97	91	88	95	90	94	83	94	94	105
800	99	91	90	90	79	97	90	90	97	90	93	83	93	91	104
1000	96	91	91	90	79	97	91	90	98	89	93	82	92	89	102
1250	92	90	89	91	78	96	89	88	94	90	93	81	91	88	101
1600	89	91	90	90	77	94	88	87	93	91	94	80	89	85	99
2000	87	91	89	90	76	93	87	84	91	89	94	80	86	81	97
2500	85	91	89	90	76	92	86	83	90	90	94	79	84	80	98
3150	84	91	91	89	74	92	85	82	88	90	93	78	81	76	100
4000	80	90	88	87	71	90	82	81	86	88	91	77	79	75	100
5000	78	90	90	87	67	91	79	82	86	88	92	78	79	69	99
6300	75	92	92	89	64	91	75	88	89	88	91	82	80	66	98
8000	72	98	97	100	64	101	73	90	99	100	101	87	80	65	100
10000	71	97	96	93	64	99	73	87	96	96	97	85	79	65	101
OVERALL	111	105	104	105	90	108	101	99	106	105	107	94	103	102	114

LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: MEASURED SOUND PRESSURE LEVEL (DB) 1/3 OCTAVE BAND														IDENTIFICATION:	
NOISE SOURCE/SUBJECT: (OPERATION:)														OMEGA 3.2	
B-52G ()														TEST CW-084-002	
INFLIGHT CREW NOISE ()														RUN 02	
()															
()														AUG 07 85	
()															
()														PAGE F2	
LOCATION/CONDITION															
FREQ (HZ)	2/G	2/H	2/I	2/K	2/L	3/D	3/E	3/F	3/G	3/H	3/I	3/K	3/L	4/D	4/E
25	80	85	79	95	89	79	77	83	84	77	78	92	90	74	71
31.5	78	82	71	82	88	69	71	83	83	70	73	80	91	66	66
40	81	80	70	76	83	67	68	82	81	72	75	76	86	67	65
50	87	79	75	79	89	71	73	85	87	77	82	83	89	75	73
63	93	79	84	86	95	77	79	88	94	80	89	87	96	79	77
80	99	84	87	88	101	80	82	91	99	82	88	89	101	78	77
100	101	82	85	88	99	81	81	94	100	83	90	89	99	79	73
125	105	89	93	92	103	86	83	97	104	90	94	93	105	80	81
160	107	90	93	90	103	81	88	97	105	89	91	94	108	83	86
200	110	87	90	92	105	84	93	103	108	87	93	93	111	84	88
250	109	90	92	93	108	91	93	104	109	88	97	95	110	89	92
315	104	92	94	93	109	91	95	104	105	91	96	95	108	86	90
400	102	89	93	94	104	91	94	107	102	89	99	97	107	94	88
500	103	94	97	94	101	96	93	106	101	92	100	97	104	97	89
630	101	96	97	94	104	94	92	106	101	95	101	95	104	95	88
800	99	95	97	91	103	94	90	106	100	95	101	92	104	93	86
1000	96	94	94	90	101	91	87	102	97	94	99	90	102	93	84
1250	97	92	94	89	100	91	85	99	94	92	96	89	100	94	83
1600	94	90	92	87	98	89	85	96	93	90	92	86	97	92	82
2000	91	89	88	85	96	87	82	97	89	91	90	83	96	89	80
2500	88	89	87	84	96	84	80	96	87	88	88	84	95	89	80
3150	86	88	84	82	99	80	76	94	84	87	85	80	94	86	76
4000	83	87	84	83	97	80	74	95	82	87	86	81	93	85	72
5000	81	88	84	84	97	79	68	95	80	88	84	83	94	90	69
6300	78	87	86	84	98	79	66	95	77	87	86	83	95	97	66
8000	77	87	87	85	98	79	65	97	77	87	87	84	95	91	65
10000	76	87	89	85	100	78	65	99	77	88	89	85	96	92	65
OVERALL	116	104	106	104	116	103	102	115	115	104	109	105	118	105	99

LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: MEASURED SOUND PRESSURE LEVEL (DB)										IDENTIFICATION:	
1/3 OCTAVE BAND											
NOISE SOURCE/SUBJECT:											
B-52G										OMEGA 3.2	
INFLIGHT CREW NOISE										TEST CM-084-002	
										RUN 04	
										AUG 07 85	
										PAGE F4	

TABLE: MEASURES OF HUMAN NOISE EXPOSURE														IDENTIFICATION:	
NOISE SOURCE/SUBJECT:														TEST CM-084-002	
(OPERATION:														RUN 01	
(B-52G															
(INFLIGHT CREW NOISE														AUG 07 85	
(
(PAGE H1	
LOCATION/CONDITION															
1/A	1/B	1/C	1/D	1/E	1/F	1/G	1/H	1/I	1/K	1/L	1/J	2/D	2/E	2/F	
HAZARD/PROTECTION															
C-WEIGHTED OVERALL SOUND LEVEL (OASLC IN DBC) AT EAR															
A-WEIGHTED OVERALL SOUND LEVEL (OASLA IN DBA) AT EAR															
MAXIMUM PERMISSIBLE TIME (T IN MINUTES) FOR ONE EXPOSURE PER DAY (AFR 161-35, JULY 73)															
NO PROTECTION															
OASLC	111	103	103	103	90	106	101	98	105	103	106	93	102	102	114
OASLA	105	104	103	103	88	107	99	98	105	103	106	93	101	99	113
T	13	15	18	18	240	9	36	42	13	18	11	101	25	36	3.2
H-157 IN-FLIGHT COMMUNICATION UNIT															
OASLA*	90	79	79	78	68	82	78	73	80	79	82	69	80	81	91
T	170	960	960	960	679	960	960	960	960	960	679	960	960	807	143
HGU-39															
OASLA*	85	75	74	74	63	78	74	69	76	74	78	64	76	77	87
T	404	960	960	960	960	960	960	960	960	960	960	960	960	960	285
H-157 PLUS U-51R															
OASLA*	81	73	73	72	60	77	71	68	76	73	76	63	73	73	84
T	807	960	960	960	960	960	960	960	960	960	960	960	960	960	480
STANDARD HGU-26/P															
OASLA*	93	81	80	79	71	85	82	76	83	80	84	71	84	85	95
T	101	807	960	960	960	404	679	960	571	960	480	960	480	404	71
HGU-26/P WITH EAR EARPLUGS															
OASLA*	80	72	72	71	60	76	71	69	75	71	75	63	73	73	84
T	960	960	960	960	960	960	960	960	960	960	960	960	960	960	480
COMMUNICATION															
PREFERRED SPEECH INTERFERENCE LEVEL (PSIL IN DB)															
PSIL	99	95	94	95	83	100	94	91	98	94	98	86	96	93	106
ANNNOYANCE															
PERCEIVED NOISE LEVEL, TONE CORRECTED (PNLT IN PNDB)															
TONE CORRECTION (C IN DB)															
PNLT	118	118	117	118	101	120	112	111	118	118	121	107	112	110	127
C	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
* BASED ON CALCULATED SPL SPECTRUM UNDER PROTECTIVE DEVICE.															

TABLE: MEASURES OF HUMAN NOISE EXPOSURE														IDENTIFICATION:	
)	
) OMEGA 3.2	
) TEST CH-084-002	
NOISE SOURCE/SUBJECT:)	
B-52G) RUN 02	
INFLIGHT CREW NOISE)	
) AUG 07 85	
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TABLE: MEASURES OF HUMAN NOISE EXPOSURE										IDENTIFICATION:	

TABLE: EFFECTIVENESS OF EAR PROTECTIVE DEVICES REDUCTION IN A-WEIGHTED OVERALL SOUND LEVEL															IDENTIFICATION:	
NOISE SOURCE/SUBJECT: (OPERATION:)															OMEGA 3.2	
B-52G ()															TEST CM-084-002	
INFLIGHT CREW NOISE ()															RUN 01	
()															AUG 07 85	
()															PAGE 11	
EFFECTIVENESS IN SPECIFIC ENVIRONMENTS																
LOCATION/CONDITION																
1/A	1/B	1/C	1/D	1/E	1/F	1/G	1/H	1/I	1/K	1/L	1/J	2/D	2/E	2/F		
OUTSIDE PROTECTIVE DEVICE																
C-WEIGHTED OVERALL SOUND LEVEL (OASLC IN DB) AT EAR																
A-WEIGHTED OVERALL SOUND LEVEL (OASLA IN DB) AT EAR																
OASLA	105	104	103	103	88	107	99	98	105	103	106	93	101	99	113	
C-A*	6	1	0	0	2	0	2	0	0	0	0	0	2	4	1	
NOISE REDUCTION (NR IN DB) OF DEVICE																
H-157 IN-FLIGHT COMMUNICATION UNIT																
NR	15	24	24	25	20	24	21	25	25	24	23	24	21	18	21	
HGU-39																
NR	21	29	28	29	25	29	25	29	29	29	28	29	25	22	26	
H-157 PLUS U-51R																
NR	24	30	30	30	28	30	28	30	30	30	30	30	28	26	29	
STANDARD HGU-26/P																
NR	13	23	22	24	17	22	17	22	23	23	22	22	17	14	18	
HGU-26/P WITH EAR EARPLUGS																
NR	25	31	31	32	27	30	28	30	30	32	30	30	28	26	29	
AVERAGE EFFECTIVENESS FOR ABOVE ENVIRONMENTS (MEAN VALUE AND STD DEVIATION OF NR IN DB)																
OASLC-OASLA (DB)																
-2 TO 0 1 TO 3 4 TO 7 8 TO 12 ABOVE 12																
N**																
H-157 IN-FLIGHT COMMUNICATION UNIT																
MEAN	21.5															
S.D.	1.6															
HGU-39	1.6															
MEAN	21.1															
S.D.	0.6															
H-157 PLUS U-51R	24.9															
MEAN	1.5															
S.D.	13.1															
STANDARD HGU-26/P	0.6															
MEAN	25.6															
S.D.	1.1															
HGU-26/P WITH EAR EARPLUGS	28.7															
MEAN	1.7															
S.D.																

* OASLC MINUS OASLA IN DB.

** NUMBER OF NR VALUES WHICH DETERMINE MEAN AND S.D.

TABLE: EFFECTIVENESS OF EAR PROTECTIVE DEVICES REDUCTION IN A-WEIGHTED OVERALL SOUND LEVEL														IDENTIFICATION:	
(NOISE SOURCE/SUBJECT: (OPERATION:))) OMEGA 3.2	
(B-52G ())) TEST CM-034-002	
(INFLIGHT CREW NOISE ())) RUN 03	
(())) AUG 07 85	
(())) PAGE 13	
(EFFECTIVENESS IN SPECIFIC ENVIRONMENTS															
(4/E 4/G 4/H 4/I 4/K 4/L 4/O 4/P 4/R 4/S 4/T 4/U 4/V 4/W 4/X 4/Y 4/Z														LOCATION/CONDITION	
(OUTSIDE PROTECTIVE DEVICE															
(C-WEIGHTED OVERALL SOUND LEVEL (OASLC IN DB) AT EAR															
(A-WEIGHTED OVERALL SOUND LEVEL (OASLA IN DB) AT EAR															
(OASLA 109 101 100 107 107 107 111 105 94 110 101 105 108 106 110 105															
(C-A* 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 0															
(NOISE REDUCTION (NR IN DB) OF DEVICE															
(H-157 IN-FLIGHT COMMUNICATION UNIT															
(NR 23 18 22 23 22 22 22 22 23 23 17 23 23 23 22 25															
(HGU-39															
(NR 28 23 27 27 26 27 28 28 21 28 23 28 28 27 27 29															
(H-157 PLUS U-51R															
(NR 30 26 29 29 29 29 30 25 29 26 29 29 29 29 29 30															
(STANDARD HGU-26/P															
(NR 19 14 19 19 19 19 19 13 18 14 19 20 19 19 19 22															
(HGU-26/P WITH EAR EARPLUGS															
(NR 30 27 28 28 28 28 29 26 29 27 29 28 28 28 28 29															
(AVERAGE EFFECTIVENESS FOR ABOVE ENVIRONMENTS (MEAN VALUE AND STD DEVIATION OF NR IN DB)															
(N** -2 TO 0 1 TO 3															
(H-157 IN-FLIGHT COMMUNICATION UNIT															
(MEAN 24.5 22.7 17.5															
(S.D. 0.4 0.6															
(HGU-39															
(MEAN 29.1 27.2 22.2															
(S.D. 0.7 0.8															
(H-157 PLUS U-51R															
(MEAN 30.4 29.1 25.9															
(S.D. 0.4 0.5															
(STANDARD HGU-26/P															
(MEAN 21.9 19.1 13.9															
(S.D. 0.4 0.5															
(HGU-26/P WITH EAR EARPLUGS															
(MEAN 29.5 28.6 26.4															
(S.D. 0.5 0.5															

* OASLC MINUS OASLA IN DB.
 ** NUMBER OF NR VALUES WHICH DETERMINE MEAN AND S.D.

TABLE: EFFECTIVENESS OF EAR PROTECTIVE DEVICES										IDENTIFICATION:	
REDUCTION IN A-WEIGHTED OVERALL SOUND LEVEL										OMEGA 3.2	
										TEST CW-084-002	
NOISE SOURCE/SUBJECT: (OPERATION:)										RUN 04	
B-52G ()											
INFLIGHT CREW NOISE ()										AUG 07 85	
()											
()										PAGE 14	
EFFECTIVENESS IN SPECIFIC ENVIRONMENTS											
6/E 6/F 6/G 6/H 6/I 6/K 6/L LOCATION/CONDITION											
OUTSIDE PROTECTIVE DEVICE											
C-WEIGHTED OVERALL SOUND LEVEL (OASLC IN DBC) AT EAR											
A-WEIGHTED OVERALL SOUND LEVEL (OASLA IN DB) AT EAR											
OASLA 93 109 101 104 107 106 110											
C-A* 3 0 3 1 1 0 1											
NOISE REDUCTION (NR IN DB) OF DEVICE											
H-157 IN-FLIGHT COMMUNICATION UNIT											
NR 18 23 19 23 24 23 23											
HGU-39											
NR 22 28 24 28 28 28 27											
H-157 PLUS U-51R											
NR 26 30 27 29 29 30 30											
STANDARD HGU-26/P											
NR 15 20 15 20 20 20 20											
HGU-26/P WITH EAR EARPLUGS											
NR 26 29 27 29 29 29 29											
AVERAGE EFFECTIVENESS FOR ABOVE ENVIRONMENTS (MEAN VALUE AND STD DEVIATION OF NR IN DB)											
-2 TO 0 1 TO 3 4 TO 7 8 TO 12 ABOVE 12											
NR** 2 5											
H-157 IN-FLIGHT COMMUNICATION UNIT											
MEAN 23.3 21.4											
S.D. 0.3 2.6											
HGU-39											
MEAN 28.1 25.9											
S.D. 0.3 2.7											
H-157 PLUS U-51R											
MEAN 29.8 28.3											
S.D. 0.1 1.7											
STANDARD HGU-26/P											
MEAN 20.4 17.9											
S.D. 0.1 2.8											
HGU-26/P WITH EAR EARPLUGS											
MEAN 29.2 28.0											
S.D. 0.0 1.1											

* OASLC MINUS OASLA IN DB.

** NUMBER OF NR VALUES WHICH DETERMINE MEAN AND S.D.

END

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